Introduction: Letter from the Director

Annual Report: 2003–2004
Letter from the NAI Director
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We live in exciting times. From an astrobiological perspective, the enduring triumph of the Mars Exploration Rovers, *Spirit* and *Opportunity* , the promise of Cassini–Huygens, and the accumulating catalog of extrasolar planets and planetary systems, are obvious highlights. We also live in interesting times. The transformation of NASA from an agency focused on the origin, future, and occurrence of life in the Universe (NASA 2003 Strategic Plan) to one with a novel Vision for Space Exploration is still underway. The broad astrobiological goals, articulated in the Strategic Plan and the Astrobiology Roadmap, remain the priorities of any enlightened civilization. But the Vision adds the important component of human exploration to create an integrated whole, which melds adventure with discovery, as only NASA can.

The NASA Astrobiology Institute (NAI) was founded by NASA in order to help develop astrobiology as a new field of knowledge, to undertake scientific research in astrobiology, and to educate and train the next generation of astrobiologists. After seven years, how are we doing?

Astrobiology is prospering. We see it in the literature (books, journals, and articles devoted solely to astrobiology), in media reports and websites, but most importantly, in people. In this report, we count nearly 800 persons who are members of the NAI. These “card–carrying astrobiologists” are only a fraction of the astrobiology community, just as NAI is only a little over a third (in dollars) of the NASA Astrobiology Program. There are are also many astrobiologists and astrobiological organizations in other nations, and the NAI, through the international Federation of Astrobiology Organizations (FAO), is in touch with most of them. Currently, the FAO is working with three other bodies that have significant astrobiological interests to develop and implement the concept of a World Congress in Astrobiology by 2010.

Within the NAI, there is ample evidence that both the field of astrobiology and the Institute are mature. Research in astrobiology, carried out by 20 current and retired NAI teams, is reported in this searchable annual compilation. Major sections comprise reports from Teams, Focus Groups, NAI Fellows,

International Partners, and lists of publications. I encourage you to browse, search, and read. There are far too many achievements to summarize here, but a few highlights may give some flavor of the variety of astrobiological science currently being undertaken by NAI teams. These are the kinds of items that are now reported each month through the NAI website and the NAI Newsletter (both at nai.nasa.gov).

- Members of former and current NAI teams (Arizona State, Harvard–MIT, Ames Research Center, SETI Institute) are hard–working members of the Athena Science Team that is operating the Mars Exploration Rovers. The NAI contributed substantially to the planning and selection of the MER landing sites through its community–wide activities and through research that was partially funded by its cooperative agreements.
- Numerical simulations carried out by NAI team members (Carnegie, University of Washington , and UCLA teams) have validated disk coalescence as a viable alternative to the long–accepted “standard model” for the formation of planetary systems and has revealed regions of orbital stability that may permit habitable worlds in the highly eccentric extrasolar planetary systems discovered recently.
- Novel approaches to measurements of the stable isotopes of carbon, sulfur and molybdenum made by members of several NAI teams (Carnegie, Harvard–MIT, UCLA, University of Colorado) are being used to probe atmospheric chemistry on the young and middle–aged Earth.

Education and Public Outreach (EPO) and training are important components of the activities of the NAI and its partner organizations. One measure of the growth of the field—and the influence of NASA's cooperative agreements with U.S. research universities upon it—is the number and quality of faculty appointments in astrobiology that have resulted from membership in the NAI. I am thinking of faculty appointees like Chris House of the Penn State team, who runs an extremophile microbiology lab in the Geosciences department, or my Australian colleagues, Roger Buick at the University of Washington, and Roger Summons at MIT. Adding up all such appointments over the last seven years reveals that several tens of junior and senior scientists have been recruited to teach and do research in astrobiology across the United States, in addition to those who transformed themselves into astrobiologists, as I did. This demonstrates enthusiasm and commitment on the part of American universities on a multi–generational timescale.

But what of the past twelve months? And what might we expect this coming year? As Deputy Director Rosalind Grymes pointed out a year ago, the NAI had effectively just turned over with the completion of new cooperative agreements for 12 of the 16 teams. At the same time, I was coming on board as the Institute's third Director.

The first step was a strategic planning retreat, held at Jackson Hole, Wyoming for Principal Investigators (PIs) and delegates from all teams, NAI Central staff, and some invited guests (October 24–26, 2003). The primary goal was to identify Institute–wide strengths within the research and EPO activities

proposed by the teams under their separate cooperative agreements. These goals could then be developed and extended as collaborative endeavors that will allow the Institute to do more than the sum of its parts. Getting to know one another and to find out about the kinds of work being done by different teams were equally important objectives. Learning to collaborate following the fierce competition required to gain membership of the NAI was, and is, an additional challenge.

Three broad cross−disciplinary themes emerged from the three−day retreat:

1. Stellar disk evolution. A meld of astronomy and cosmochemistry using new telescopic observations, small special scale chemistry of early solar system materials (meteorites, comets, asteroids, dust particles), plus theory and numerical modeling, to investigate the fate of astrobiologically important components of the dusty disks up to the stage of planet formation. The plan is to organize three workshops, each leading to a multi−authored review article in a peer−reviewed journal, that will define the principal scientific problems that need further investigation. This initiative is being led by Ed Young, PI of the UCLA team. The three proposed workshops will deal with disk timescales, ices/icy bodies, and disk chemistry; the first is scheduled for this Fall.
2. Subsurface life. Expanded to encompass life in extreme environments in subsequent discussions, this topic brings together NAI expertise in the geosciences, oceanography, microbiology, and molecular biology. The goals of this group, as expressed in Jackson Hole , are both deep (irony intended) and forward−looking. One is to investigate microbial communities that might be metabolically divorced from the light of the sun. There have been many reports of communities that rely solely on geothermal energy sources but closer examination usually indicates that some metabolite is ultimately derived from organisms or processes that depend upon oxygenic photosynthesis. A second focus is on cold (cryospheric) environments and the microbes that inhabit them. Plans are underway, led by the Indiana−Princeton−Tennessee team (IPTAI), to explore the microbes in Canadian permafrost as an analogy for possible subsurface life on Mars. A third, ambitious goal is to work with industrial partners to develop a down−hole microbiology lab. Bruce Jakosky, PI of the University of Colorado at Boulder NAI team, led the Jackson Hole discussions and a follow−up one−day workshop held in conjunction with the Astrobiology Science Conference (AbSciCon 2004) in March. Leadership of the initiative was passed over to Tullis (T.C.) Onstott of the IPTAI team at that that time.
3. Planet in transition. A developing concept, which probably needs to be re−named, is aimed at using NAI geosciences expertise to inform planners of missions that will eventually be able to observe planets orbiting nearby stars. Discoveries in geochemistry made over the past few years are reinforcing the idea that the Earth has passed through a series of fundamentally different steady states during its 4.6 billion year history. From an astronomical point of view, these steady states are most obviously reflected in the chemical composition and oxidation state of the atmosphere and oceans. Each state is spectroscopically unique. Transitions between states are short compared with the

billion–year lifetimes of the separate states. For this endeavor, the plan is to form working groups for successive Earth states (Hadean, Archean, Proterozoic) under the aegis of the NAI's Early Earth Focus Group. The overall project leader is Peter Ward, PI of the University of Washington team.

These are not the only Institute–wide initiatives that were being nurtured and fertilized with Institute funds during the reporting period. Perhaps the most important activities, both in terms of dollars spent and potential knowledge gained, were the founding projects of the Astrobiology Drilling Program (ADP). Other activities, reviewed briefly below, include the first ever Astrobiology Graduate Conference (AbGradCon) at the University of Arizona in January; NAI's participation in AbSciCon 2004 in March; the second NAI Field Workshop to the oldest sedimentary rocks on Earth in southwest Greenland June; the now–annual Summer School in Astrobiology, taught jointly by the NAI and the Spanish Centro de Astrobiología in Spain, in July; two NAI–organized geochemistry symposia at the National Meeting of the American Chemical Society in Philadelphia in August; and an NAI–led workshop on Mars Astrobiology Science and Technology in Washington in September.

But to return to the ADP. An international consortium funded by Kagoshima University, The University of Western Australia, the Geological Survey of Western Australia, and the Pennsylvania State University NAI team led by Hiroshi Ohmoto, completed six diamond drill holes in Archean (3.5 to 2.7 billion–year–old) sedimentary and volcanic strata of Western Australia during the summer of 2003. This Archean Biosphere Drilling Project (ABDP) is the founding project of the Astrobiology Drilling Program. Its goals were to obtain unweathered, uncontaminated, and unoxidized samples of astrobiological importance from an ancient terrain that has been subjected to tropical conditions for millions of years. The cores are now being analyzed for traces of Earth's early life and to understand the environments in which it lived.

A second set of holes was drilled during the summer of 2004. Once again, the ABDP was involved, but this time in partnership with a second drilling project that came into being as a result of discussions and collaborations developed within the NAI's Mission to Early Earth Focus Group. This second project, the Deep Time Drilling Project (DTDP), is managed by Roger Buick of the University of Washington NAI team. However, funding for the analysis of the longest interval drilled this year—a one–kilometer succession in the Hamersley Basin of Western Australia—has been provided by a separate grant from the National Science Foundation. The organic geochemical analyses will be carried out in Roger Summons' state–of–the–art biomarker lab at MIT and stable isotopic surveys will take place in Ariel Anbar's new lab at Arizona State University . Both Summons and Anbar are members of NAI teams (Ames Research Center and University of Washington , respectively). The first results of the ABDP and DTDP projects will be reported in a session on astrobiology drilling projects organized by Ohmoto, Anbar, and myself at the Fall Meeting of the American Geophysical Union (San Francisco , December 2004). Additional information on the ADP and its projects is available at: nai.nasa.gov/ADP

AbGradCon (January, 2004) was the brain−child of Maggie Turnbull, then a graduate student in Astronomy at the University of Arizona, and now an NAI Postdoctoral Fellow with Sara Seager of the Carnegie Institution of Washington team. Maggie and her helpers organized everything: Speakers, talks, tours, and accommodations and food. It was remarkable. Only graduate students were allowed to present; only about a third of those who came were from NAI teams; and the talks and posters were confident, novel, exciting, multidisciplinary, and, above all, broad. This was a glimpse of the new generation of astrobiologists which the NAI is helping to train. Conference abstracts were subsequently published in *Astrobiology* , marking the first foray into the scientific literature for many of the AbGradCon participants.

AbSciCon (March, 2004) is the NASA−supported international meeting on astrobiology that alternates on a yearly basis with the NAI's own “all hands” meeting. NAI has the odd years; AbSciCon the even ones. So “NAI 2005” is scheduled for April 10−14, 2005 and will be hosted by the University of Colorado team in Boulder . However, NAI also supports and participates substantially in AbSciCon, and did so this year with additional meeting at each end. During the weekend before, the NAI held an enlarged two−day meeting of its Executive Council, which was enlivened by a visit from the NASA Administrator, Mr. Sean O'Keefe. He used the opportunity to explain the new Exploration Vision to the Council and its guests. They included representatives from our international partner organizations in Australia , Italy , Mexico , the Netherlands , Russia , Spain , Sweden , and the United Kingdom as well as countries that are in the process of developing organizations or affiliations (Canada , Japan , Russia , South Africa). Also present were Education and Public Outreach personnel from the NAI teams and partner organizations such as museums (see EPO section of this report for details). The remainder of the meeting was largely given over to scientific/organizational updates from the international guests and presentations by the team EPO leaders and their community−wide colleagues. And, of course, NAI as a whole helped fund, organize, and present AbSciCon.

Akilia, Godthaabsfjord, and Isua (June, 2004). Transcendental names to those in the know, these were the field sites for the second NAI Field Workshop, organized by UCLA team member Craig Manning and Minik Rosing, a Greenlander from the Geological Museum, Denmark. The event was timed to follow the 2004 Goldschmidt Geochemistry conference in Copenhagen and began with heated discussions in three symposia on the Early Earth and Astrobiology, organized by NAI members and colleagues in the Nordic countries (www.goldschmidt2004.dk). Participants in the Field Workshop then decamped to the Greenland Nature Institute where inclement weather (for helicopters) forced a schedule of field days interspersed with presentations and discussions in the fabulous facilities in Nuuk. As many of the major players involved in understanding the astrobiological significance of Earth's earliest sedimentary rocks (now severely metamorphosed) were on hand, many contentious issues were aired, discussed, and re−discussed at length. In particular, the 1999 report by University of Colorado team member Stephen Mojzsis, then a graduate student at the University of California , San Diego , of biogenic graphite within apatite grains on the island of Akilia was re−examined frankly and openly in all possible ways. It is now clear that the observation

needs to be verified by repetition and Alan Nutman, who provided the original sample, offered to supply additional subsamples for future analysis. On the other hand, Manning and Mojzsis presented fine field evidence and powerful geochemical arguments that the Akilia host rock was, indeed, once a sediment. Others have seriously doubted this claim. Thus, the Field Workshop achieved its principal goals: To provide field access to the finest outcrops and to enable group sampling so that different labs can analyze exactly comparable materials. However, the Greenland climate did thwart one major objective of the Field Workshop: Rosing's sedimentary graphite particles from Isua, currently the best evidence for the existence of life on Earth 3.8 billion years ago, remained under snow. The NAI will need to return!

Planet Mars (July, 2004). For the last three summers, the NAI has co−taught a graduate−level course in Astrobiology with the Spanish Centro de Astrobiología. Juan Pérez Mercader and I have been co−Directors of each course and there is a continuing agreement that they will be presented as one of the famous summer schools of the Universidad Internacional Menéndez Pelayo (UIMP) at its seasonal campus, the Palacio de Magdalena, on the Cantabrian coast of Spain . This year, the topic was “Planet Mars”, aimed at presenting all aspects of the planet, from core to atmosphere, to budding and no−so−budding astrobiologists. It was an absolute treat for the 40 participants. David Paige, from the UCLA team, first reviewed the planet and its atmosphere and hydrosphere. Then Laurie Leshin, Arizona State University and a member of the President's Commission on Space Exploration, presented the planetary geochemistry as revealed by Martian meteorites and spacecraft. Three talks on the Mars Exploration Rovers from Steven Squyres, Cornell University , who had just returned from Endurance Crater and was decompressing after months of intense activity, were a highlight of the week. But there was equally exciting news from Mars Express, reviewed by European Space Agency (ESA) Head of Research, Álvaro Giménez, and from Cassini−Huygens, given in a well−attended evening public lecture by the PI of the Titan Surface Science Package (a.k.a. “lander”), John Zarnecki, from the Open University. The school closed with an afternoon field trip to a nearby Cretaceous−Tertiary (K−T) boundary interval, where we imagined dinosaurs and ammonites going extinct. Images of the school diplomates and field trip participants are available at nai.nasa.gov/PlanetMars.

ACS, Philadelphia (August, 2004). Astrobiologists from the NAI organized and participated in two cross−disciplinary symposia at the 228th National Meeting of the American Chemical Society, held in Philadelphia , August 22−26. Aravind Asthagiri from the Carnegie team and his in−town colleague at George Washington University , H. Henry Teng, convened two very full days on “Astrobiology and the Origin of Life”; many of the 39 talks in the symposium were presented and/or co−authored by members of the NAI. Highlights included: Tice and Lowe (Stanford) on the hydrothermal control of early Earth ocean chemistry; Wang, Huang and Pizzarello's work (Brown and Arizona State universities) on the extraordinary (interstellar?) deuterium enrichment of some amino acids and other compounds from the Murchison meteorite; and Robert Hazen's (Carnegie team) presentation of Simon Platts' concept of a “PAH world” which he developed to help explain steps leading to the origin of life during his time as a Ph.D. student at RPI.

Boswell (Boz) Wing from the University of Maryland (and associate of the Carnegie team) and his NAI colleague James Lyons from the UCLA team convened a one−day symposium on “Mass−independent Isotope Fractionation” in conjunction with a week−long review of “Chemical Physics in Atmospheric Science” organized by the ACS Division of Physical Chemistry. For the first time at a major meeting, geoscientists studying the rock and ice−core records of atmospheric gas−phase reactions were able to hear and discuss the novel oxygen and sulfur chemistry that may be responsible for the anomalous isotopic effects. Applications ranged from understanding processes in the early Solar nebula (Thiemens, UC San Diego) to the use of anomalous oxygen isotope ratios to discriminate between fertilizer−derived and natural perchlorate levels in environmental assessments (Bao and Gu, LSU and Oak Ridge NL). Most of the presentations from NAI members focused on the use of anomalous sulfur isotope effects to track Earth's atmospheric history from an early anoxic stage through the “Great Oxidation Event”, just over two billion years ago.

Workshop on Mars Astrobiology Science and Technology (September, 2004).

This workshop was organized by the leaders of the new NAI Focus Group on Astrobiology Science and Technology with financial and other support from NASA HQ, the NAI, the NASA/JPL Mars Program Office, and the Carnegie Institution of Washington. The mix of engineering and science made cross−field communication a challenge but a great deal was achieved behind the scenes and in local restaurants. The Carnegie auditorium is spectacular but overpowering and tended to dampen debate. It was an important first step and a learning experience for all concerned. Look forward to hearing more from this crucial NAI Focus Group in twelve months time.

In closing, let me say that one of the pleasures of taking up this job as NAI Director has been the opportunity to work with the talented and dedicated staff of NAI Central at the Ames Research Center . Allow me to remind you that the Institute functions as a distributed organization largely through their hard work and enlightened stewardship. Please let them know, from time to time, how much you appreciate their efforts.

Bruce Runnegar

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